Statement of

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Examining the 'Hockey Stick' Controversy

Submitted to

Committee on Energy and Commerce
Subcommittee on Oversight and Investigations
U.S. House of Representatives

July 27, 2006

Mr. Chairman, Ranking Member, and Members of the Committee:

Thank you for the opportunity to speak today. I am Jay Gulledge, Ph.D., Senior Research Fellow for Science and Impacts at the Pew Center on Global Climate Change. I am also an Adjunct Assistant Professor at the University of Louisville, which houses my academic research program on carbon cycling.

The Pew Center on Global Climate Change is a non-profit, non-partisan and independent organization dedicated to providing credible information, straight answers and innovative solutions in the effort to address global climate change. In our eight years of existence, we have published almost seventy reports by experts in climate science, economics, policy and solutions, all of which have been peer-reviewed and reviewed as well by the companies with which we work.

Forty-one major companies sit on the Pew Center's Business Environmental Leadership Council, spanning a range of sectors, including oil and gas (BP, Shell), transportation (Boeing, Toyota), utilities (PG&E, Duke Energy, Entergy), high technology (IBM, Intel, HP), diversified manufacturing (GE, United Technologies), and chemicals (DuPont, Rohm and Haas). Collectively, the 41 companies represent two trillion dollars in market capitalization and three million employees. The members of the Council work with the Pew Center to educate the public on the risks, challenges and solutions to climate change.

If you take nothing else from my testimony, please take these three points:

1. The scientific evidence of significant human influence on climate is strong and would in no way be weakened if there were no Mann hockey stick.

2. The scientific debate over the Medieval Warm Period (MWP) has been gradually evolving for at least 20 years. The results of the Mann hockey stick simply reflect the gradual development of thought on the issue over time.

3. The impact of the McIntyre and McKitrick critique on the original Mann paper, after being scrutinized by the National Academy of Science, the Wegman panel and a number of meticulous individual research groups, is essentially nil with regard to the conclusions of the Mann paper and the 2001 IPCC assessment.

The science of climate change is an extraordinary example of a theory-driven, data-rich scientific paradigm, the likes of which, arguably, has not occurred since the development of quantum mechanics in the first half of the twentieth century. The product of this strong scientific framework is a body of strong, multifaceted evidence that man-made greenhouse gases are causing contemporary global warming, and that this warming

trend is inducing large-scale changes in global climate. The primary evidence is based on physical principles and observational and experimental analysis of contemporary climate dynamics, as opposed to analyses of past climates, which are the subject of this hearing. We can now say with confidence that the evidence of human influence on climate is strong, as described by Dr. Cicerone.

Although paleoclimatology – the study of ancient climates – is an important part of the climate science frame work, reconstructions of temperature over the past millennium play a secondary, expendable role in the larger body of evidence, as stated in the recent NAS report titled, *Surface Temperature Reconstructions for the Last 2,000 Years*: "**Surface temperature reconstructions are consistent with other evidence of global climate change and can be considered as additional supporting evidence**" (National Research Council 2006, p. 23; hereafter referred to as the NAS report). Dispensing with such reconstructions entirely or proving them fundamentally flawed would have little, if any, impact on our understanding of contemporary climate change. This statement does not imply that millennial climate reconstructions are unimportant, but their main influence will be in the future, when their potential to reveal how climate varied across the earth's surface from year-to-year in the past (i.e. an annual record of spatially explicit climate dynamics) is fully realized. At that point, such reconstructions will be used in a manner parallel to thermometer records today. This capability would contribute significantly to resolving the current genuine debate in climate science, which is not about whether humans are changing the climate—a point over which there is no scientific controversy—but is about how much human influences will change the climate in the future as a result of greenhouse gas accumulation and other forcings we apply to

the climate system. In other words, the goal of spatially explicit paleoclimate reconstructions is to help climatologists determine how physical forcings, such as solar radiation, volcanic eruptions, land-use changes, and changes in atmospheric greenhouse gases, have affected the planet in the past, so that we can improve estimates of how they will do so in the future.

The early MBH reconstructions (Mann et al. 1998; Mann et al. 1999; hereafter referred to as MBH98 or MBH99 or, collectively, MBH) were the first to offer spatially explicit climate reconstructions and therefore represented a breakthrough in climate change science that continues to develop and promises to further our understanding of climate physics in the future. The Wegman report's conclusion that paleoclimatology "does not provide insight and understanding of the physical mechanisms of climate change" (p. 52), fails to appreciate that the purpose of Dr. Mann's research is to improve our knowledge of physical mechanisms of climate change by examining how they operated in the past.

Turning our attention to the methodological issues this hearing seeks to investigate, in my opinion, the Wegman report failed to accomplish its primary objective, which was "**to reproduce the results of [McIntyre & McKitrick] in order to determine whether their criticisms are valid and have merit**" (p. 7). Although the panel reproduced MM's work—verbatim—it only partially assessed the validity, and did not at all assess the merits, of the criticisms directed toward the MBH reconstructions. For instance, MM (McIntyre and McKitrick 2003; McIntyre and McKitrick 2005; heafter referred to collectively as MM) allege that the so-called MBH "hockey stick" result is biased by methodological errors that undermine the conclusion that the late 20th century

was uniquely warm relative to the past 1000 years. This critique only has merit if, after correcting for the errors pointed out by MM, the resulting reconstruction yields results significantly different from the original result that can no longer support the claim of unusual late 20th century warmth. However, the Wegman Report takes no steps to make such a determination.

Fortunately, a different group, one well qualified both statistically and climatologically to tackle this question of merit, had already performed the task several months before the Wegman Report was released. The study by Wahl & Ammann (In press; hereafter referred to as WA06), was peer-reviewed and accepted for publication in the journal, *Climatic Change*, early last spring, and has been publicly available in accepted form since last March (http://www.cgd.ucar.edu/ccr/ammann/millennium/refs/WahlAmmann_ClimChange2006.html). This study, titled, **Robustness of the Mann, Bradley, Hughes Reconstruction of Northern Hemisphere Surface Temperatures: Examination of Criticisms Based on the Nature and Processing of Proxy Climate Evidence**, carefully reproduced the MBH98 reconstruction and then used their faithful reproduction to test MM's suggested corrections. They tested each of the criticisms raised by MM in all of their published papers, including both the peer-reviewed and non-peer-reviewed papers. Given that this report specifically examined MM's criticisms, including the decentering issue that was the main focus of the Wegman report, it is unfortunate that the Wegman report dismissed it in a footnote (p. 48) as "not to the point."

WA06 have performed a meticulous and thorough evaluation of MBH98, and the answers that this committee seeks about the MBH reconstructions are to be found within this report. After examining each of MM's three methodological criticisms, WA06

accepted two of them as valid, and have used them to correct the MBH98 reconstruction. I will now show you what effect these corrections have on the MBH98 reconstruction, and then reconsider the uniqueness of the late 20th-century warming trend in the light of these corrections.

The original MBH98 "hockey stick" is shown as a gray line (Fig. 1). The WA06 reproduction of MBH98 is shown in red (Fig. 1). Except for a couple of minor simplifications, WA06 remained faithful to the original MBH method and retained all of the original MBH data, including the original instrumental temperature series from 1992. They wrote their own computer code to perform the calculations, using the R programming language, as recommended by the MM and the Wegman report, rather than the original Fortran language used by Dr. Mann. As you can see, the two reconstructions are materially the same. This result demonstrates that MBH98 can be reproduced based on information available in the original MBH papers and supplemental information and data available on the Internet.

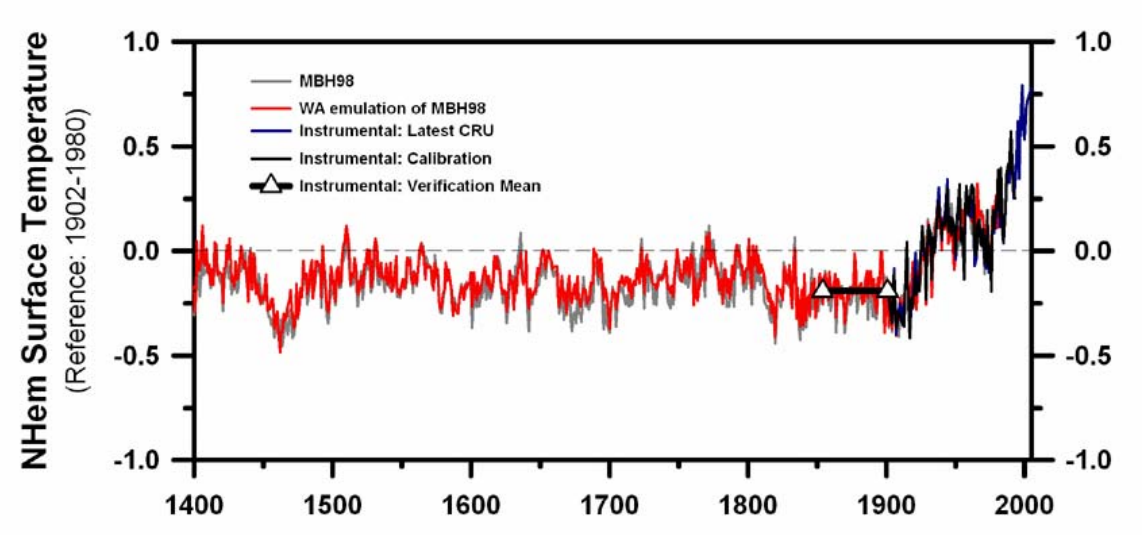

Fig. 1. WA06 reproduction of MBH98 reconstruction. The gray line is the original MBH98 reconstruction. The red line is the WA06 emulation. The black line is the original 1992 instrumental data used for calibration. The blus line is the latest instrumental data. The black bar with triangles represents the mean of the instrumental mean of the verification period.

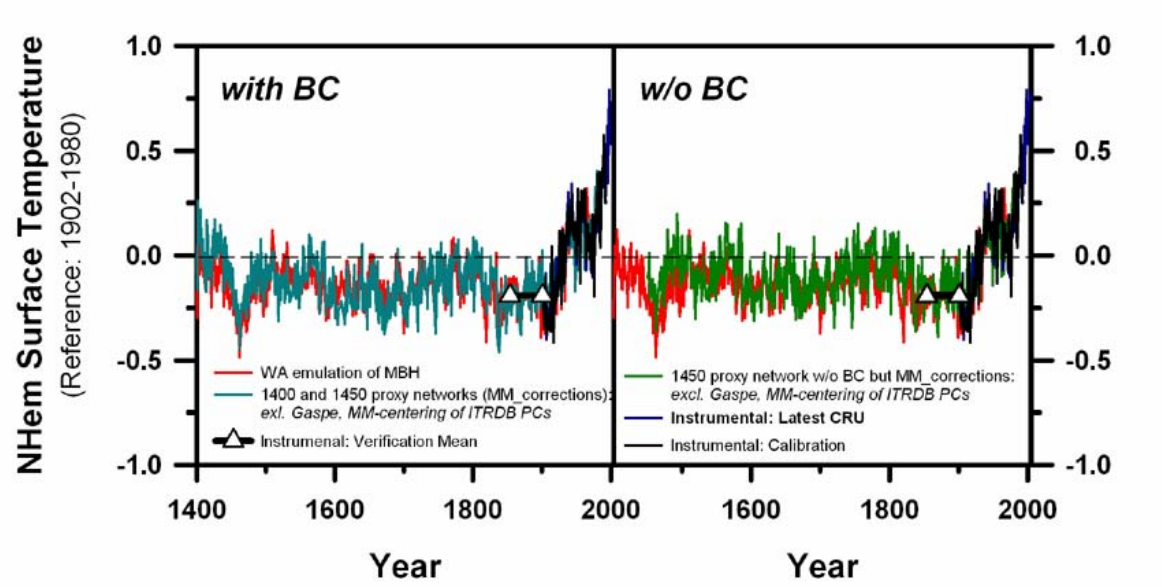

Fig. 2. WA06 corrections of MBH98 for accepted MM corrections. The left frame shows original WA06 emulation of MBH in red and the corrected reconstruction accounting for decentering and excluding the Gaspe tree-ring series in blue. The right frame shows the same but with the bristle cone pine series removed (green line). Instrumental data are shown in black.

With this successful reproduction in hand, WA06 were able to test the effects of each of MM's criticisms on the outcome of the MBH98 reconstruction. After carefully considering the validity of MM's three criticisms of MBH's reconstruction methodology, WA06 agreed that 1) decentering the proxy data prior to Principle Component analysis and 2) including the poorly replicated North American Gaspé tree-ring series from 1400-1449 both affected the MBH results. After correcting for these effects, WA06 obtained the results shown in blue (Fig. 2, left frame). The result is a slightly warmer (0.1 °C) early 15th century, with no other time period affected. MM's third methodological criticism surrounding the inclusion of the bristlecone/foxtail pine series was rejected for several reasons. The right frame in Fig. 2 illustrates that excluding these series has little effect on the MBH98 reconstruction, except to force it to begin in 1450 instead of 1400,

because of lack of a data. Since the exclusion had little effect, and losing these data series would hinder reconstructions of earlier climate, WA06 rejected this criticism.

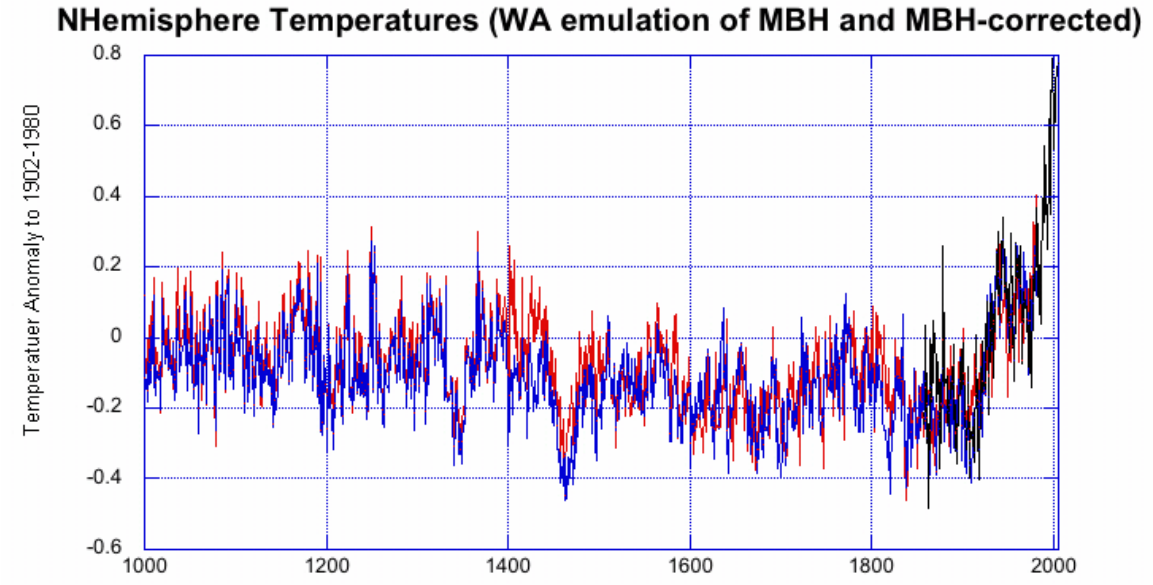

Fig. 3. Wahl-Ammann corrections of the MBH99 reconstruction (Ammann & Wahl, submitted). The original MBH99 reconstruction is shown in blue and the corrected WA version is shown in red. Corrections were made for the decentering issue and the Gaspe tree-ring series. Instrumental data are in black.

The additional 15th-century warmth revealed by making the valid MM corrections still does not approach the warmth of the late 20th century, so MM's critique cannot yet be said to have merit. However, the corrected result creates the impression of an upward temperature trend backward in time before 1400, begging the question of what would happen to the Middle Ages in the 1000-year MBH99 reconstruction if it were also corrected? Answering that question is requisite for determining the merit of MM's critique of MBH. The original 1000-year MBH99 reconstruction is shown in blue and the corrected version is shown in red (Fig. 3; Ammann & Wahl, submitted). Carrying the correction back to the full millennium reveals that the largest effects remain in the early 15th century, and both earlier and later periods were less affected. Therefore, there is very little difference between the corrected MBH98 and MBH99 reconstructions and the

originals, and the original observation that the late 20th century is uniquely warm in the context of the past 1000 years is not affected. Hence, the valid methodological caveats that MM pointed out do not undermine the main conclusions of the original MBH papers or the conclusion of the 2001 IPCC assessment.

The scientific debate over the Medieval Warming Period (MWP) has been on the same trajectory for at least 20 years, with early indications that the MWP was not a globally coherent event becoming more solid over time. The MBH99 reconstruction represented an evolutionary step—not a revolutionary change—in this established trajectory. The 1990 IPCC figure that Mr. McIntyre, the *Wall Street Journal* editorial page, and Dr. Wegman have used in their own assessment of past climate is a cartoon, as stated by Dr. Wegman in his testimony last week. I have confirmed this with a number of individuals who were involved with the 1990 IPCC report or with versions of the schematic that pre-dated the 1990 IPCC report. The schematic is not a plot of data and is inappropriate as a comparison to MBH. The text of the 1990 IPCC report clearly states that the figure is a "schematic diagram" and that "it is still not clear whether all the fluctuations indicated were truly global" (p. 202). Furthermore, only three sources of information were cited and those sources conflicted on whether the Northern Hemisphere was warm or cold: **"The late tenth to early thirteenth centuries… appear to have been exceptionally warm in parts of western Europe, Iceland and Greenland… China was, however, cold at this time, but South Japan was warm…"** Clearly, this report certainly did not paint a picture of any consensus regarding a Medieval Warm Period as a hemisphere-wide phenomenon and characterizing it as such reveals a fundamental misunderstanding of climate science.

The 1992 and 1995 IPCC reports continued this same trajectory of thought. Four years before MBH99, citing 6 papers—still a very limited number by twice as many as were cited in 1990—the 1995 report stated:

> There are, for this last millennium, two periods which have received special attention, the Medieval Warm Period and the Little Ice Age. These have been interpreted, *at times*, as period of global warmth and coolness, respectively. Recent studies have re-evaluated the interval commonly known as the Medieval Warm Period to assess the magnitude and geographical extent of any prolonged warm interval between the 9th and 14th centuries… The available evidence is limited (geographically) and is equivocal. …a clearer picture may emerge as more and better calibrated proxy records are produced. However, at this point, it is not yet possible to say whether, at a hemispheric scale, temperatures declined from the 11-12th to the 16-17th century. Nor, therefore, is it possible to conclude that the global temperatures in the Medieval Warm Period were comparable to the warm decades of the late 20th century" (p. 174).

Remember that this was written by a team of climatologists as a consensus statement. The consensus at this time, as in 1990, was that there was no strong evidence of a hemisphere-wide MWP.

Continuing the same trajectory, the 2001 IPCC Third Assessment Report examined evidence from 10 cited sources for the MWP. The consensus at this point seemed to be turning to the conclusion that the there actually was a generally warm Northern Hemisphere during the Middle Ages, but that it was not a strong, coherent pattern of warming:

> It is likely that temperatures were relatively warm in the Northern Hemisphere as a whole during the earlier centuries of the millennium, but it is much less likely that a globally-synchronous, well defined interval of

> "Medieval warmth" existed, comparable to the near global warmth of the late 20th century… Marked warmth seems to have been confined to Europe and regions neighboring the North Atlantic.

Since the MBH reconstructions were hemisphere-wide, and the MWP probably was not, it should not surprise us that the reconstructions lack a strong MWP (MBH99 does show slightly warmer temperatures in the 9th to 14th centuries than in the 15th to 19th centuries).

All available evidence indicates that the situation during the Middle Ages was fundamentally different that what is happening with climate today, which is a well-documented, globally coherent warming trend that is happening North, South, East, and West; at low latitudes and high latitudes; over land and over—and into—the sea. There are new data, published earlier this year, indicating that the atmosphere above Antarctica has warmed dramatically in recent decades (Turner et al. 2006). There is no large region on Earth where large-scale 20th century warming has not been detected, which simply cannot be said of the MWP.

Wahl and Ammann (2006) have demonstrated that the results of MBH are robust "down in the weeds":

> Our examination does suggest that a slight modification to the original Mann et al. reconstruction is justifiable for the first half of the 15th century (~ +0.05°), which leaves entirely unaltered the primary conclusion of Mann et al. (as well as many other reconstructions) that both the 20th century upward trend and high late-20th century hemispheric surface temperatures are anomalous over at least the last 600 years.

The NAS has affirmed the MBH results are also robust in the bigger picture, as well:

> The basic conclusion of MBH99 was that the late 20th century warmth in the Northern Hemisphere was unprecedented during at least the last 1,000 years.

> This conclusion has subsequently been supported by an array of evidence that includes both additional large-scale surface temperature reconstructions and pronounced changes in a variety of local proxy indicators, such as melting on icecaps and the retreat of glaciers around the world, which in many cases appear to be unprecedented during at least the last 2,000 years. Not all individual proxy records indicate that the recent warmth is unprecedented, although a larger fraction of geographically diverse sites experienced exceptional warmth during the late 20th century than during any other extended period from A.D. 900 onward. (p. 3)

Examination of the IPCC reports through time, as well as the primary scientific literature, reveals why the MBH results are so robust—MBH simply assimilated all the available evidence into a quantitative reconstruction—evidence that had already been evaluated qualitatively as lacking a coherent MWP.

This committee is seeking to know the significance of the criticisms leveled at the MBH reconstruction for climate change assessments. The significance is that these criticisms have resulted in the most thoroughly vetted single climate study in the history of climate change research. Dr. Tom Karl summarized the impact most succinctly in his testimony to this committee last week when he said that he would stand by the IPCC's original assessment: "If you ask me to give qualifications about the findings in the 2001 report with the same caveat in terms of defining likelihood, I personally would not change anything." Hence, the impact of the MM critique, after being scrutinized by the NAS, the Wegman panel, and a number of meticulous individual research groups, is essentially nil with regard to the conclusions of MBH and the 2001 IPCC assessment.

Also relevant to this committee's questions about climate change assessments is the revelation that climate scientists do know their business, and that a lack of knowledge of geophysics is a genuine handicap to those who would seek to provide what they deem

"independent review." If the assessment of climate science presented in Mr. McIntyre's presentation to the NAS committee, the Wegman Report, and the WSJ is an example of what can be expected from those who have not conducted climate research, then the investigation launched by this committee has demonstrated clearly that "independent review" by non-climate scientists is an exceedingly ineffective way to make climate change assessments.

References

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Wahl, E and C Ammann (In press). "Robustness of the Mann, Bradley, Hughes reconstruction of northern hemisphere surface temperatures: Examination of criticisms based on the nature and processing of proxy climate evidence." *Climatic Change* (accepted).

Examining the 'Hockey Stick' Controversy

Testimony to the
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Jay Gulledge, Ph.D.
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Global Climate Change Basics

- Human activities are increasing atmospheric greenhouse gases (GHG) (unequivocal)
- The earth is warming (unequivocal)…
- …at an unprecedented rate (confident)
- Warming over past 5 decades caused primarily by man-made GHG (confident)
- Effects of warming are being observed now: **Sea-level rise, glacier melting, more frequent and intense heat waves, more intense storms** (confident)
- Warming will continue for a long time, even after GHG stabilize (confident)

Main Points

- The so-called “hockey-stick controversy” is actually not a controversy, scientifically.
- Criticisms of the “hockey stick” in no way undermine the science of climate change. It is not central to our understanding of climate change.
- The results of the hockey stick represent the gradual development of scientific understanding of past climate, not a step-change.
- Climate change assessments are working well under the supervision of climatologists.

Hockey Stick Basics

NAS report

Surface Temperature Reconstructions for the Last 2,000 Years
June 2006

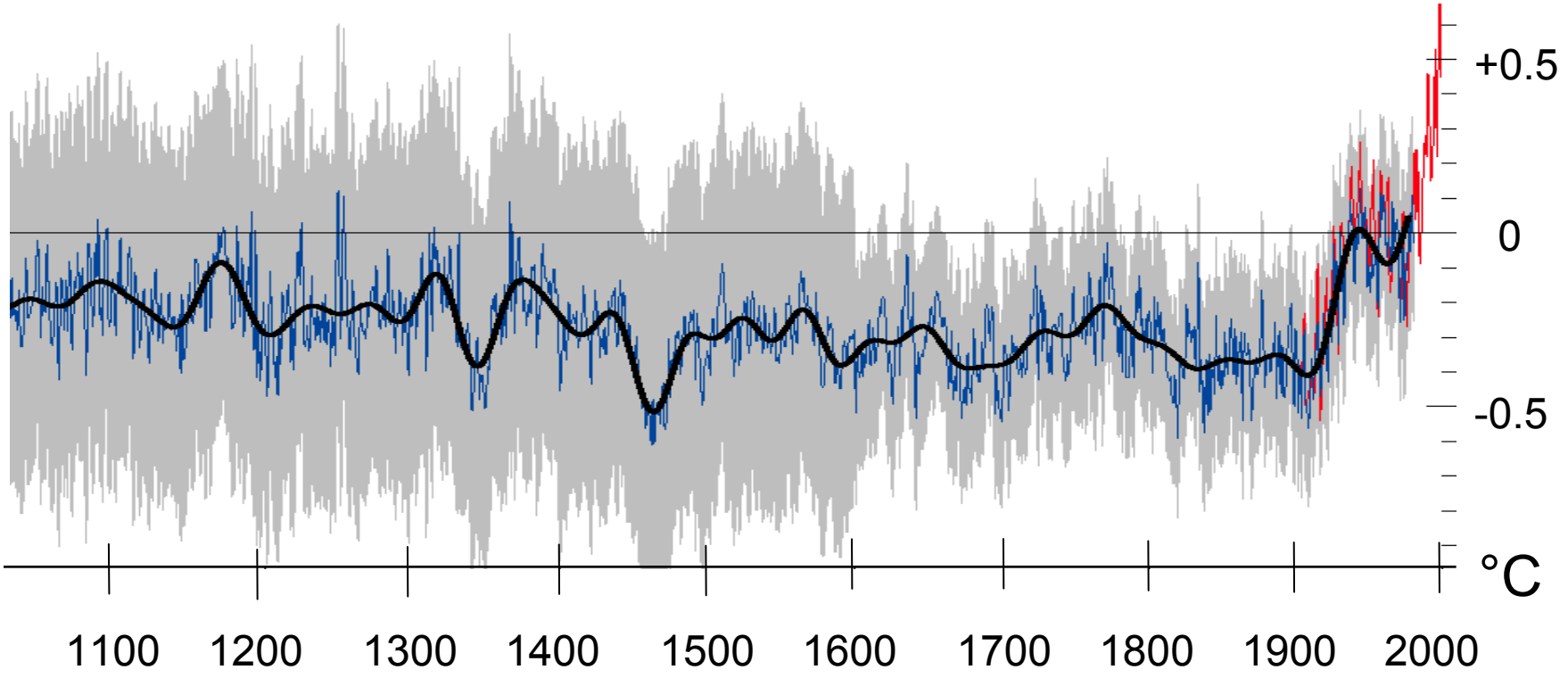
The basic conclusion of [the hockey stick study] was that the late 20th century warmth in the Northern Hemisphere was unprecedented during at least the last 1,000 years. This conclusion has subsequently been supported by an array of evidence…(p. 3)

Surface temperature reconstructions [such as the hockey stick] are consistent with other evidence of global climate change and can be considered as additional supporting evidence. (p. 23)

Hockey Stick Basics

The Mann "Hockey Stick"

A 'reconstruction' of average Northern Hemisphere temperature for the last 1000 years

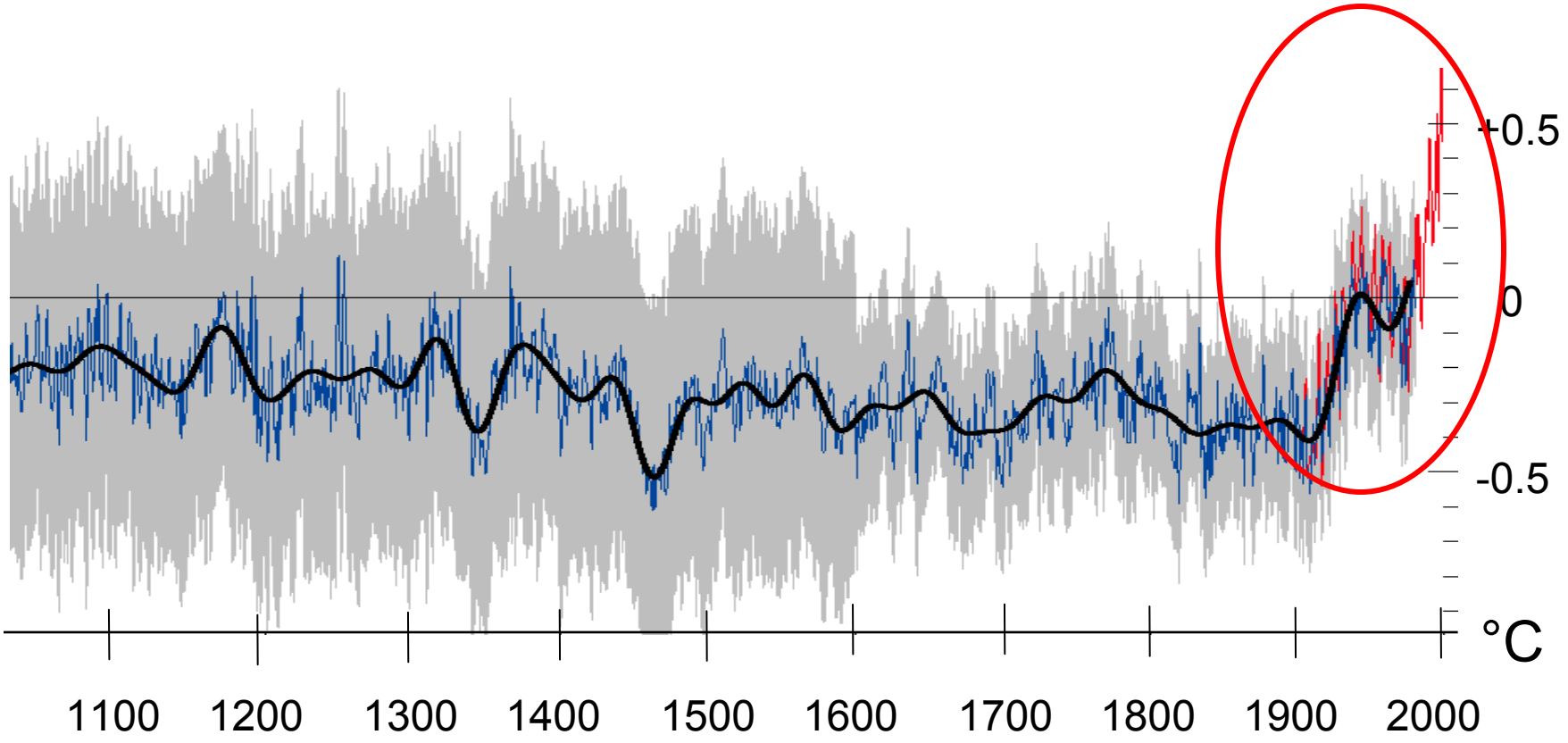


Mann 1998 (*Nature*), 1999 (*Geophysical Research Letters*)

Hockey Stick Basics

Main Conclusion

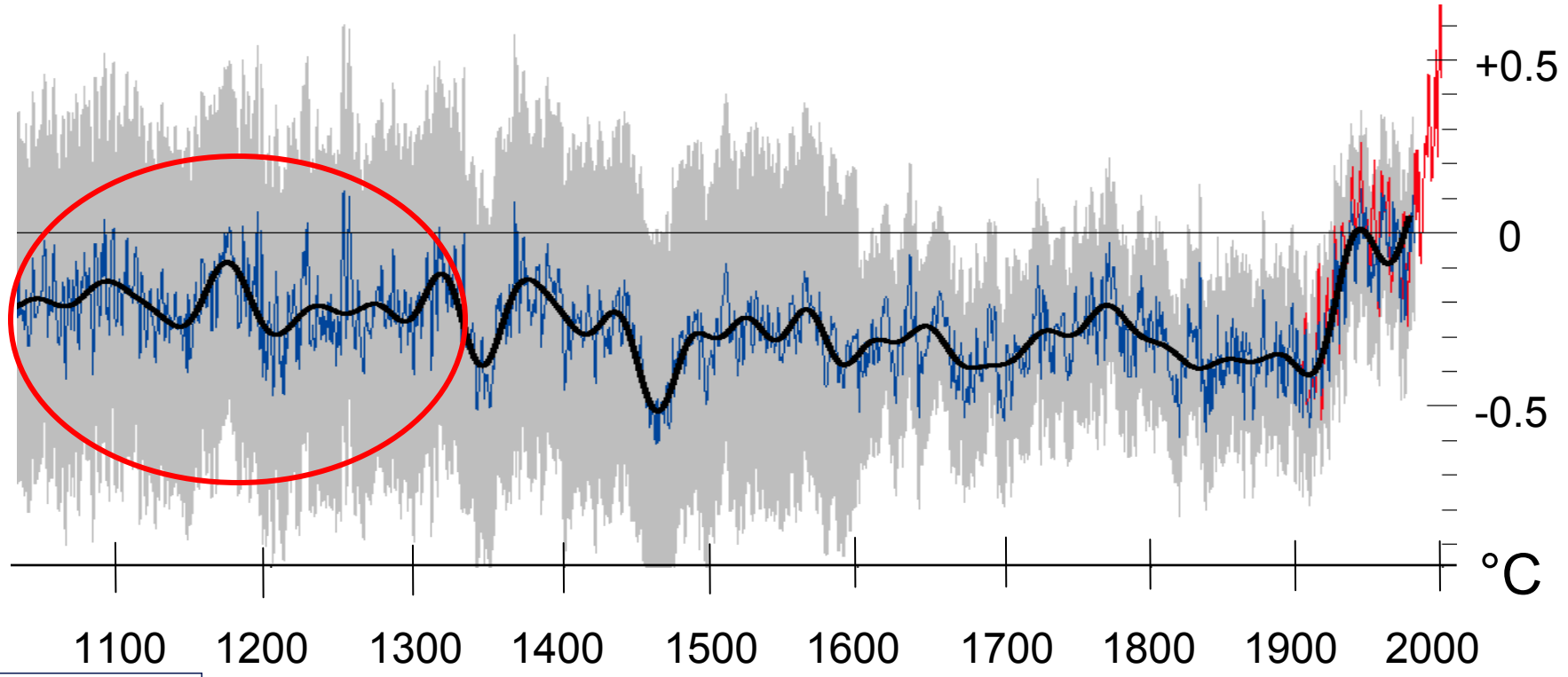
- 20th Century warmest in past 1000 years
- 1990s warmest decade in past 1000 years



Hockey Stick Basics

McIntyre & McKitrick Complaints

- Statistical methods not applied properly
- Inappropriate data used
- Incorrectly eliminates Medieval Warm Period



Wegman Report, July 2006

Objective of Wegman report:

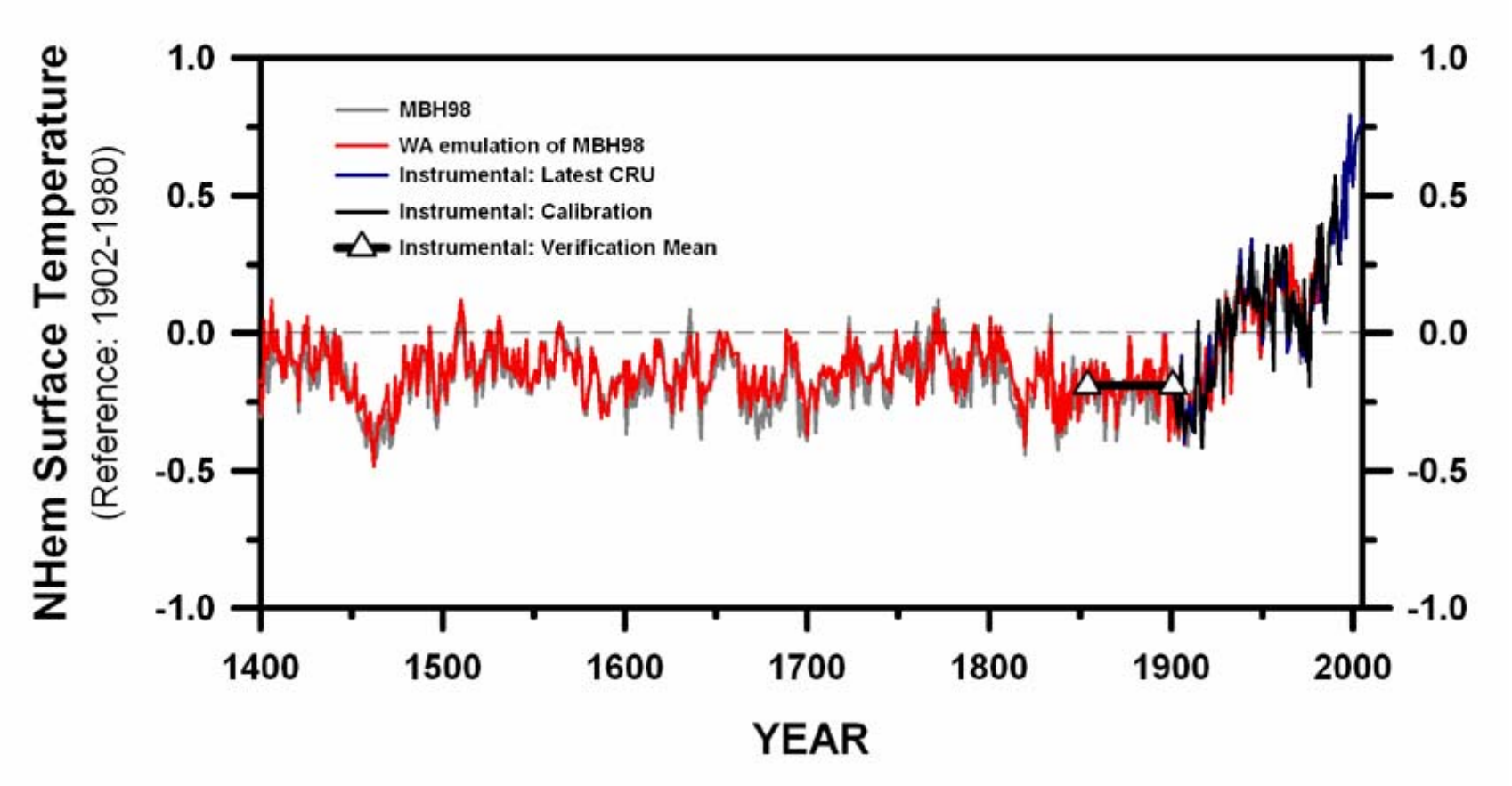
"to reproduce the results of [McIntyre & McKitrick] ***in order to determine whether their criticisms are valid and have merit***"

(p. 7)

Wegman Report, July 2006

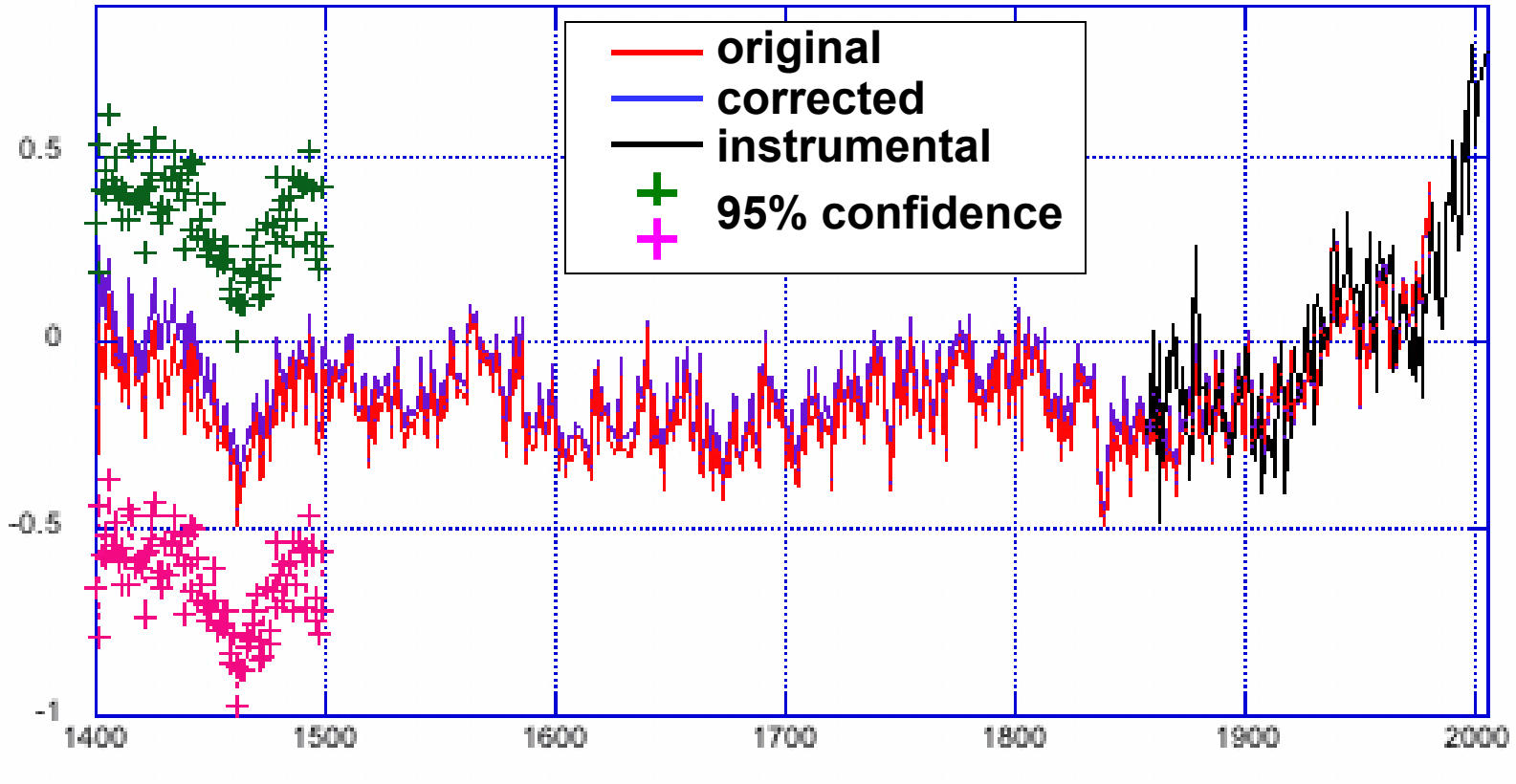
- Mann's newer methods were not tested.
- Mann's claim that McIntyre & McKitrick didn't apply his method correctly was not tested.
- Corroborating evidence was not examined
  - other reconstructions using different methods/proxies
  - evidence from glaciers
- Wahl & Ammann paper overlooked
  - Examined all 4 of MM's main criticisms
    - Decentering
    - Gaspe tree-ring series
    - Bristlecone/foxtail pine data
    - Verification statistic thresholds

Wahl & Ammann (2006)



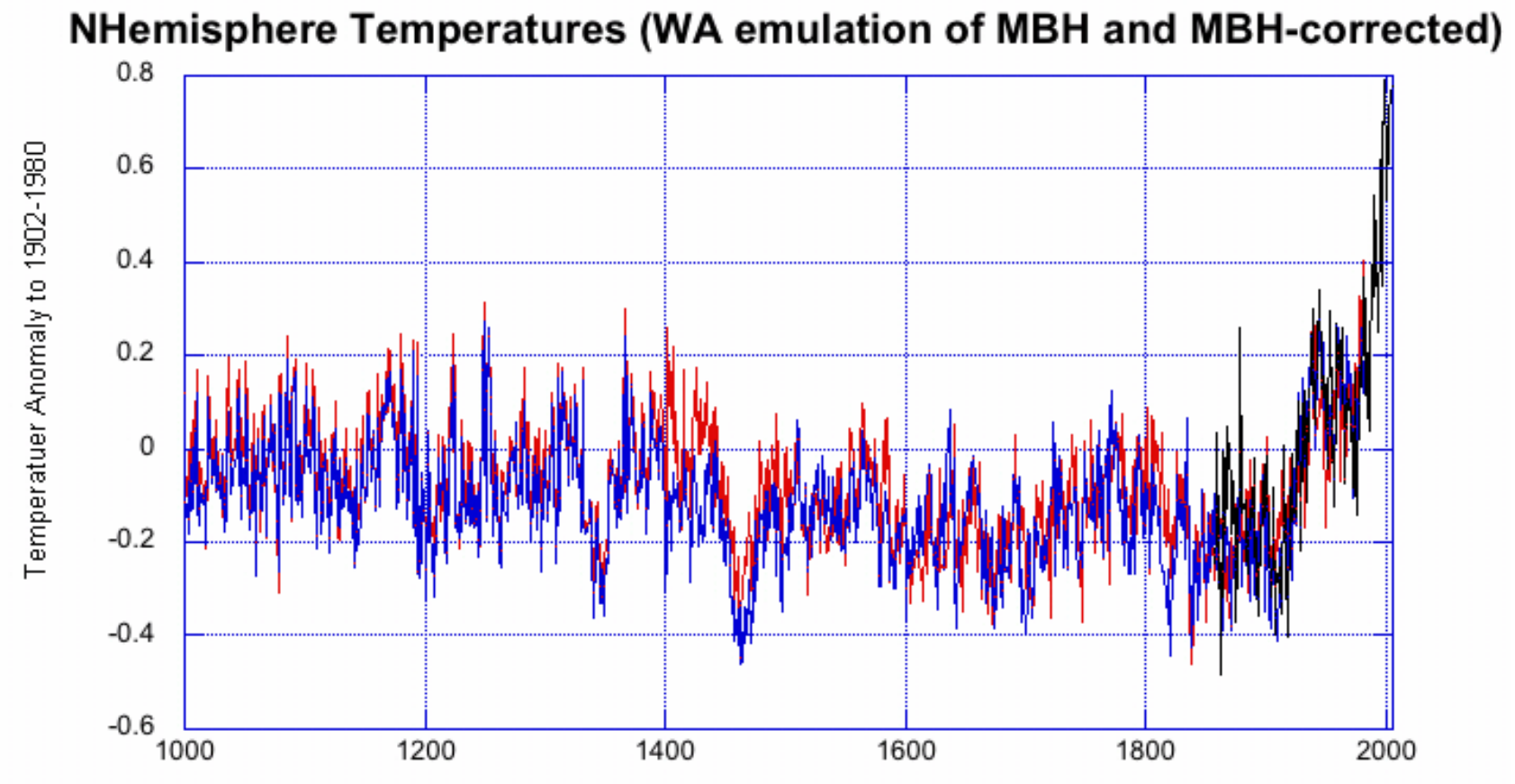
Wahl & Ammann (2006)

Correction of MBH98 for decentering and Gaspe tree-ring series



Ammann & Wahl (submitted)

Correction of MBH99 for decentering and Gaspe tree-ring series



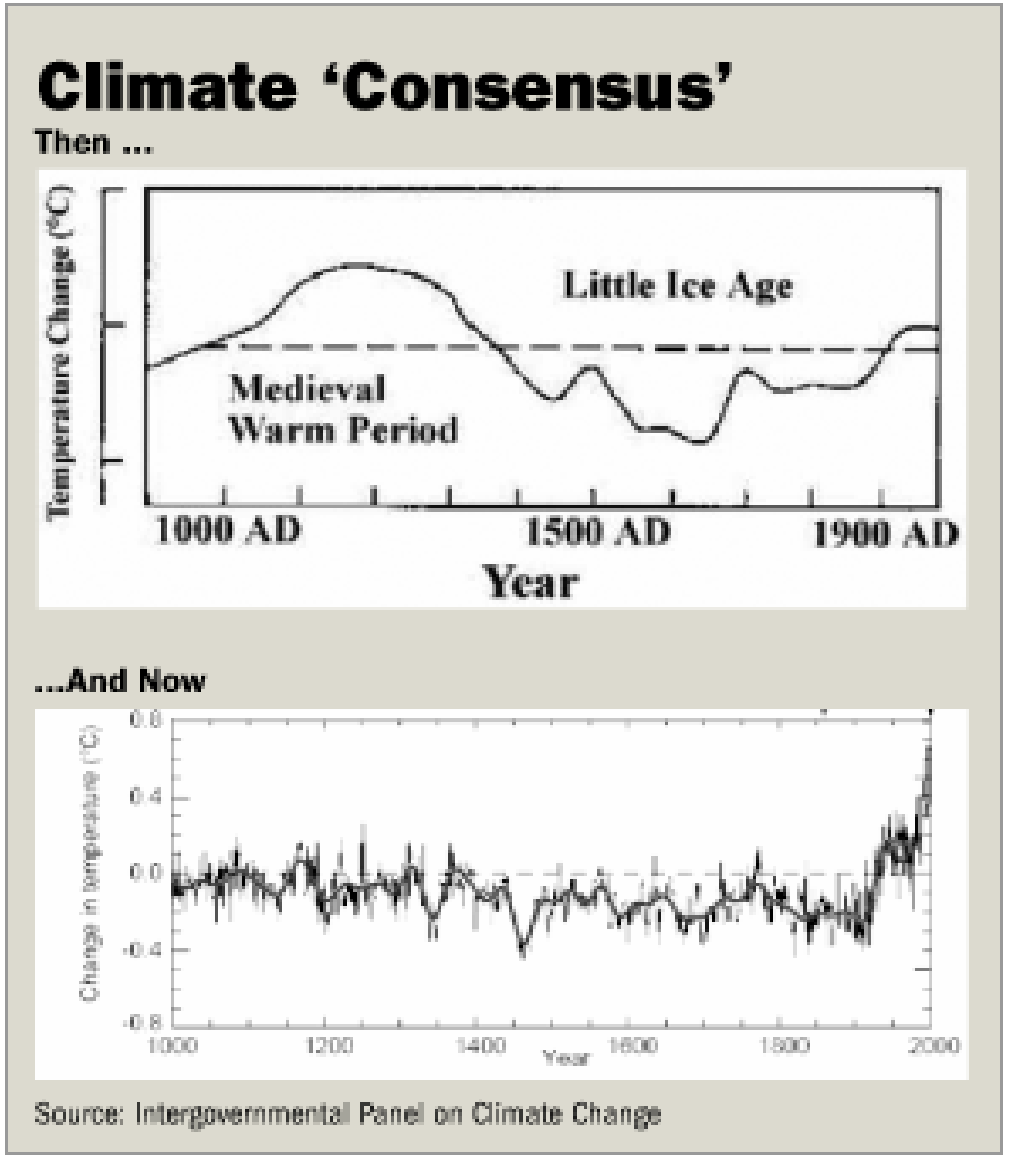
After Corrections to MBH98/9

- Wahl & Ammann corrected for
  - Decentering
  - Gaspe tree-ring series
- Wahl & Ammann rejected MM's objection about the bristlecone/foxtail pines on grounds they did not affect reconstruction and were necessary
- Corrected reconstructions support the conclusions that late 20th century warmth is unique relative to the last millennium.

The Medieval Warm Period

1990 IPCC ***schematic diagram***

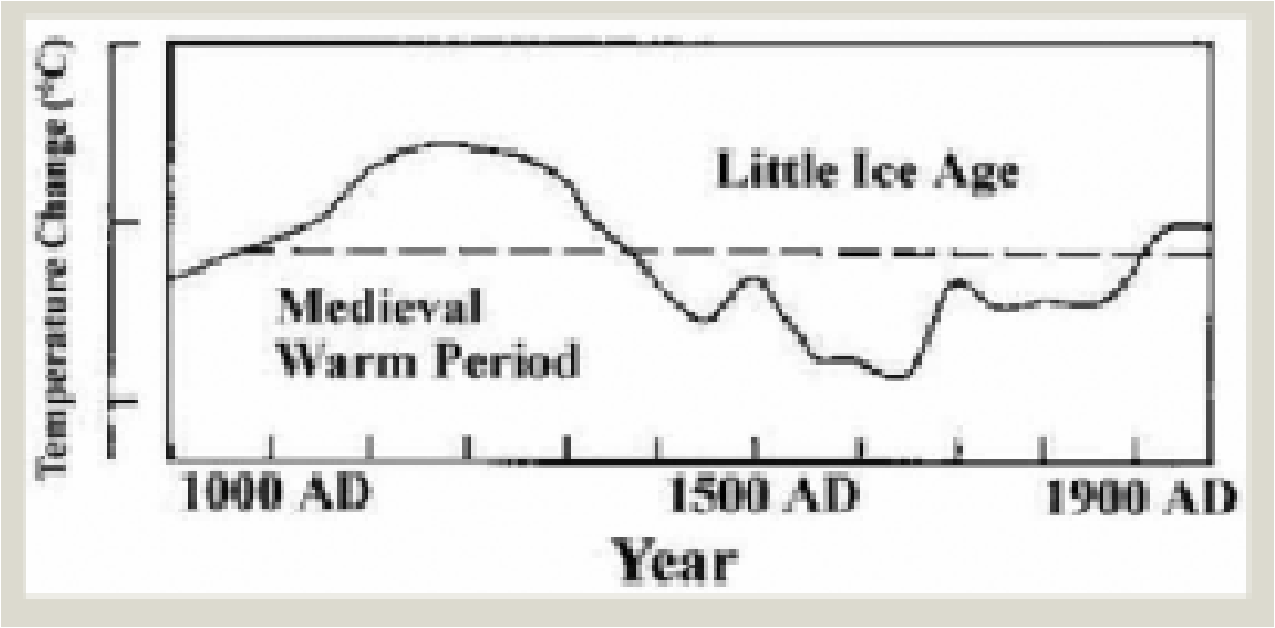
1999 hockey stick ***graph***



The Medieval Warm Period

1990 IPCC Assessment:

…it is still not clear whether all the fluctuations indicated [in the diagram] were truly global.



The Medieval Warm Period

WSJ Editorial "Hockey Stick Hokum" (July 14)

"Prior to Dr. Mann's work, the accepted view, as embodied in the U.N.'s 1990 report from the [IPCC], was that the world had undergone a warming period in the Middle Ages…"

"That CONSENSUS… held that the Medieval warm period was considerably warmer than the present day."

"Mr. Mann's 1999 paper eliminated the Medieval warm period from the history books, with the result being the [hockey stick]"

The Medieval Warm Period

Before the 'Hockey Stick'

1993: Sukumar et al. (Nature 364:703): *"…a wet phase in Southern India about 600 years ago… appears to correspond to the [MWP], which previously was believed to be confined to Europe and North America."*

1994: Hughes & Diaz. Was there a Medieval Warm Period, and if so, where and when? (Climatic Change 26:109): *"…the available evidence does not support a global [MWP]…"*

The Medieval Warm Period

After the 'Hockey Stick'

2001: Broeker, Was the Medieval Warm Period Global?" (Science 291:1497): *"[I will try] to make the case that the [MWP] was global rather than regional… Evidence for the [MWP] from other parts of the world (besides the N. Atlantic region) exists but is spotty and/or circumstantial… The case for a global [MWP] admittedly remains inconclusive."*

The Medieval Warm Period

From the IPCC Assessments:

1990, 3 papers cited

…the late tenth to early thirteenth centuries appear to have been exceptionally warm in western Europe, Iceland and Greenland… China was, however, cold at this time… but South Japan was warm.

The Medieval Warm Period

From the IPCC Assessments:

1995, 6 papers cited

Recent studies have re-evaluated the interval commonly known as the Medieval Warm Period… The available evidence is limited (geographically) and is equivocal…

…a clearer picture may emerge as more and better calibrated proxy records are produced. However, at this point, it is not yet possible to say whether, at a hemispheric scale, temperatures declined from the 11-12th to the 16-17th century.

Nor, therefore, is it possible to conclude that the global temperatures in the Medieval Warm Period were comparable to the warm decades of the late 20th century.

The Medieval Warm Period

From the IPCC Assessments:

2001, 10 papers cited

It is likely that temperatures were relatively warm in the Northern Hemisphere as a whole during the earlier centuries of the millennium, but it is much less likely that a globally-synchronous, well defined interval of "Medieval warmth" existed, comparable to the near global warmth of the late 20th century.

Marked warmth seems to have been confined to Europe and regions neighboring the North Atlantic.

The Medieval Warm Period

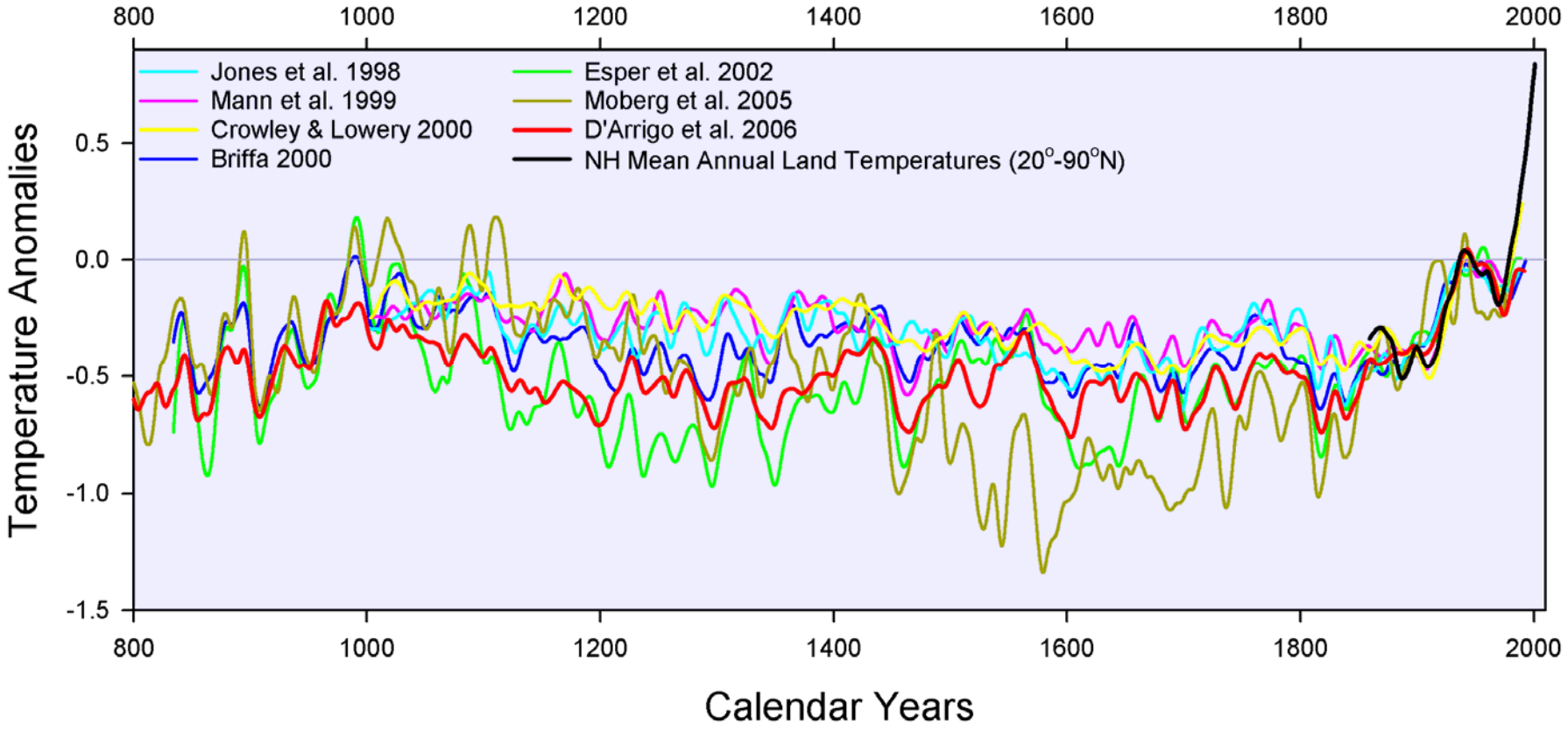
- Mainstream scientific debate on the extent of the Medieval Warm Period continues today.
- Balance of evidence indicates the Medieval Warm Period was not consistent throughout the Northern Hemisphere.
- The MBH99 results simply quantified what the evidence already suggested about the Medieval Warm Period.

Climate Change Assessments

- The assessment of the state of climate science that led to the improper use of a schematic drawing from the 1990 IPCC report to support the existence of a strong Medieval Warm Period, is incorrect.
- Through time, successive IPCC reports accurately reflected the state of knowledge about the climate of the past 1000 years.
- These assessments work, and the alternative assessment that has been offered by Mr. McIntyre is not accurate.
- The assessment of climate science is best performed by those with geophysical understanding of climate.

Hockey Stick Basics

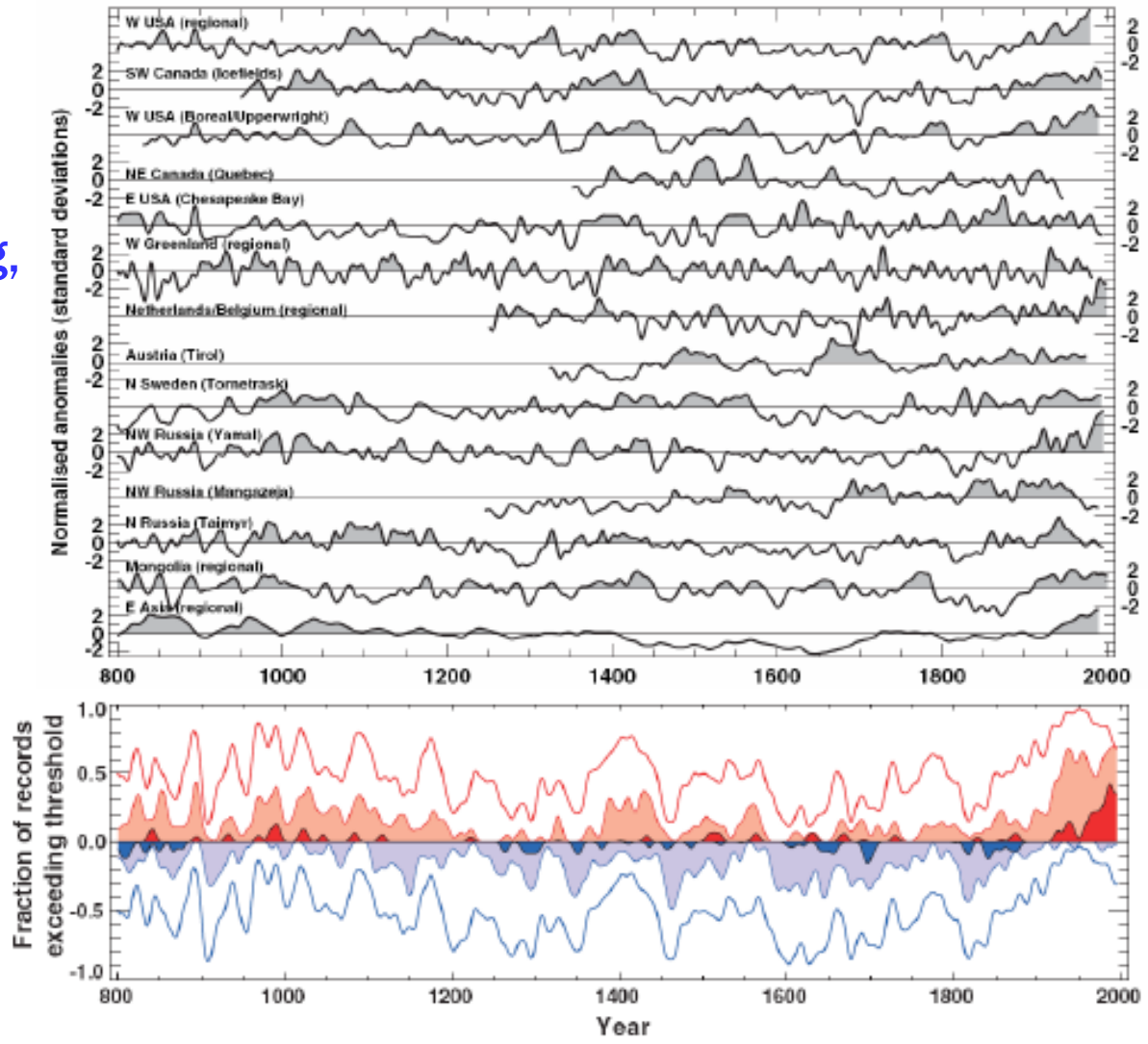
- Regardless of criticisms, Mann's main conclusions stick
- All reconstructions to date support the hockey stick study



D'Arrigo 2006

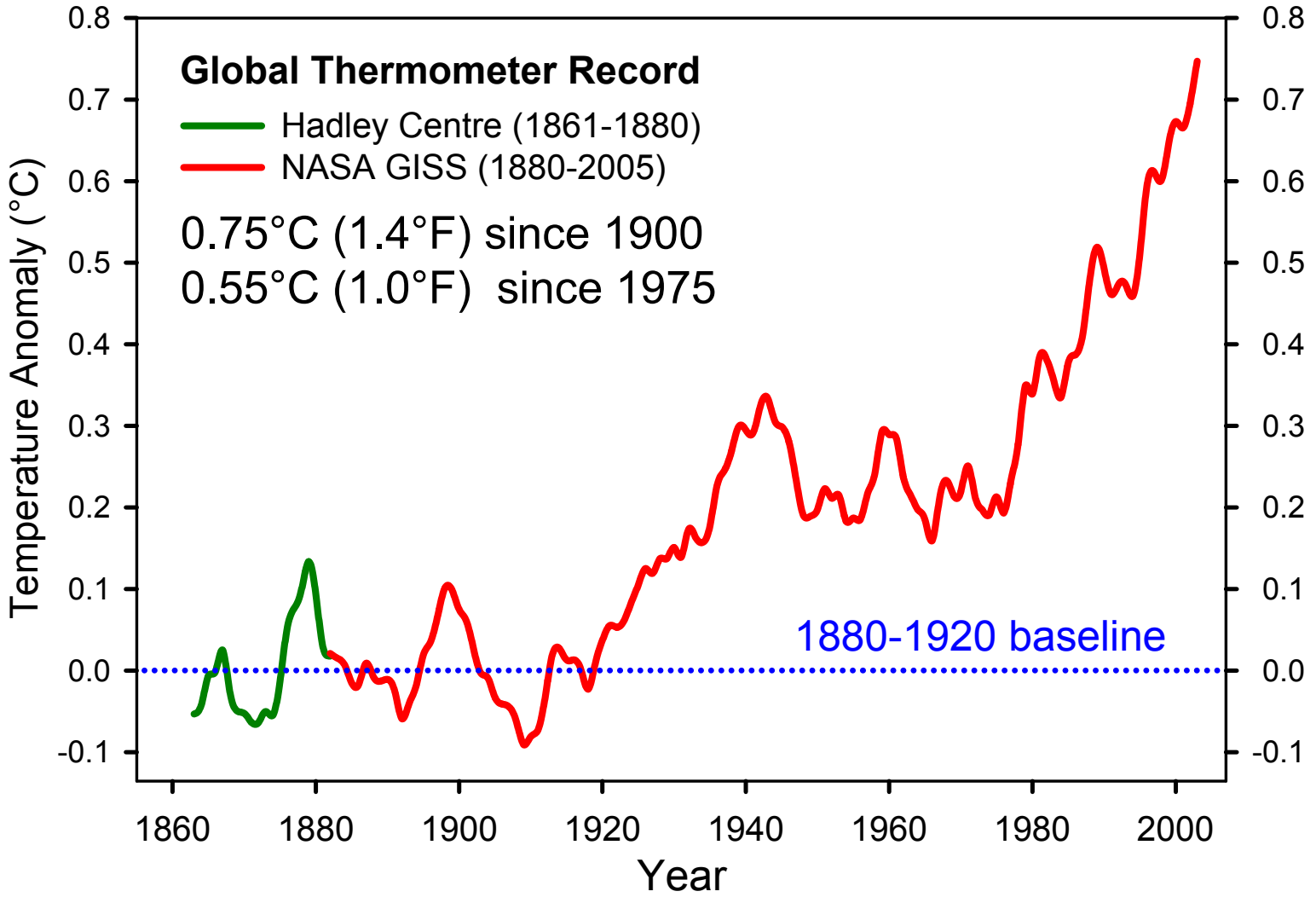
Hockey Stick Basics

A new study using no fancy statistics, just simple averaging, supports the original Mann conclusions.

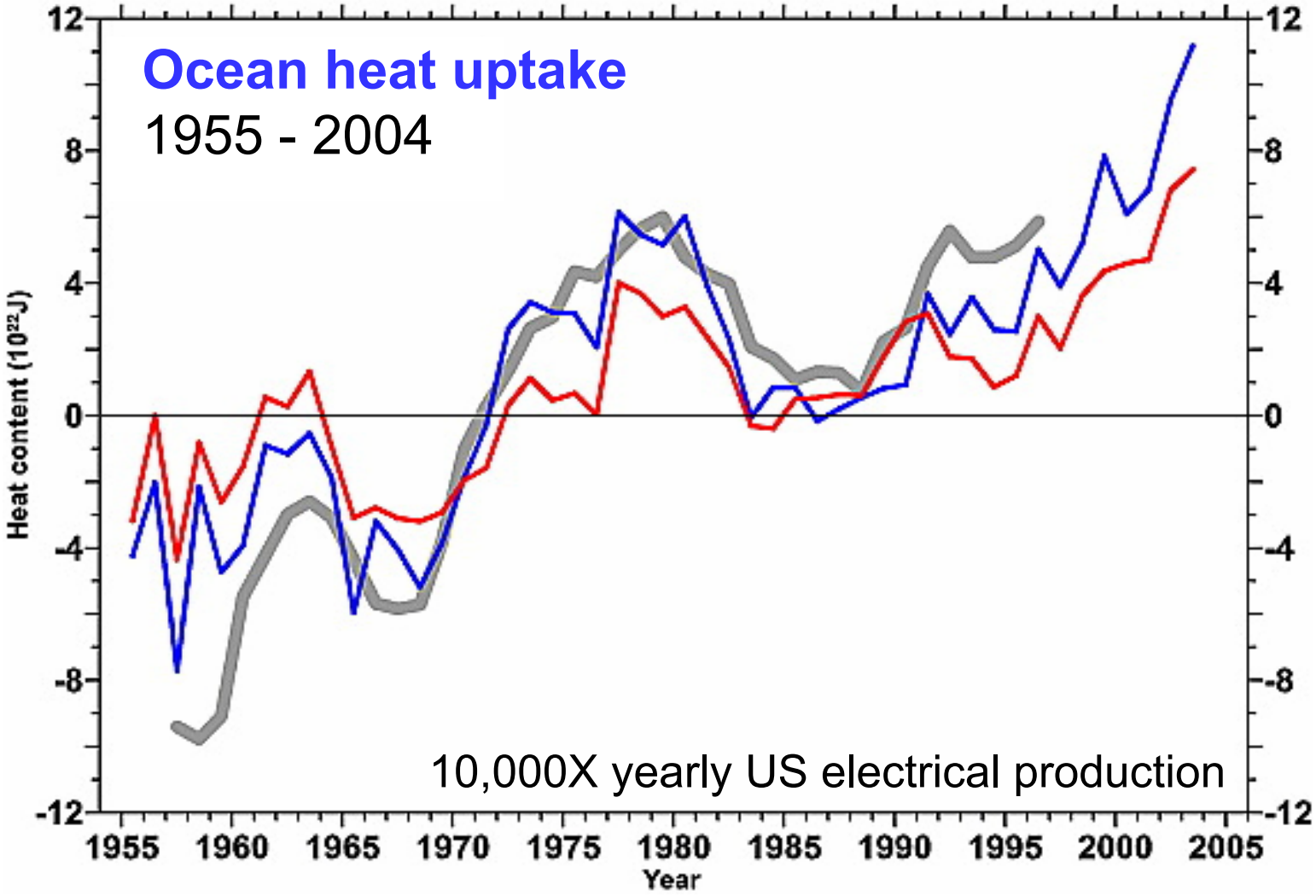


Osborn 2006, *Science* 311:841

Global Climate Change Basics



Global Climate Change Basics



Levitus 2005, *Geophysical Research Letters*

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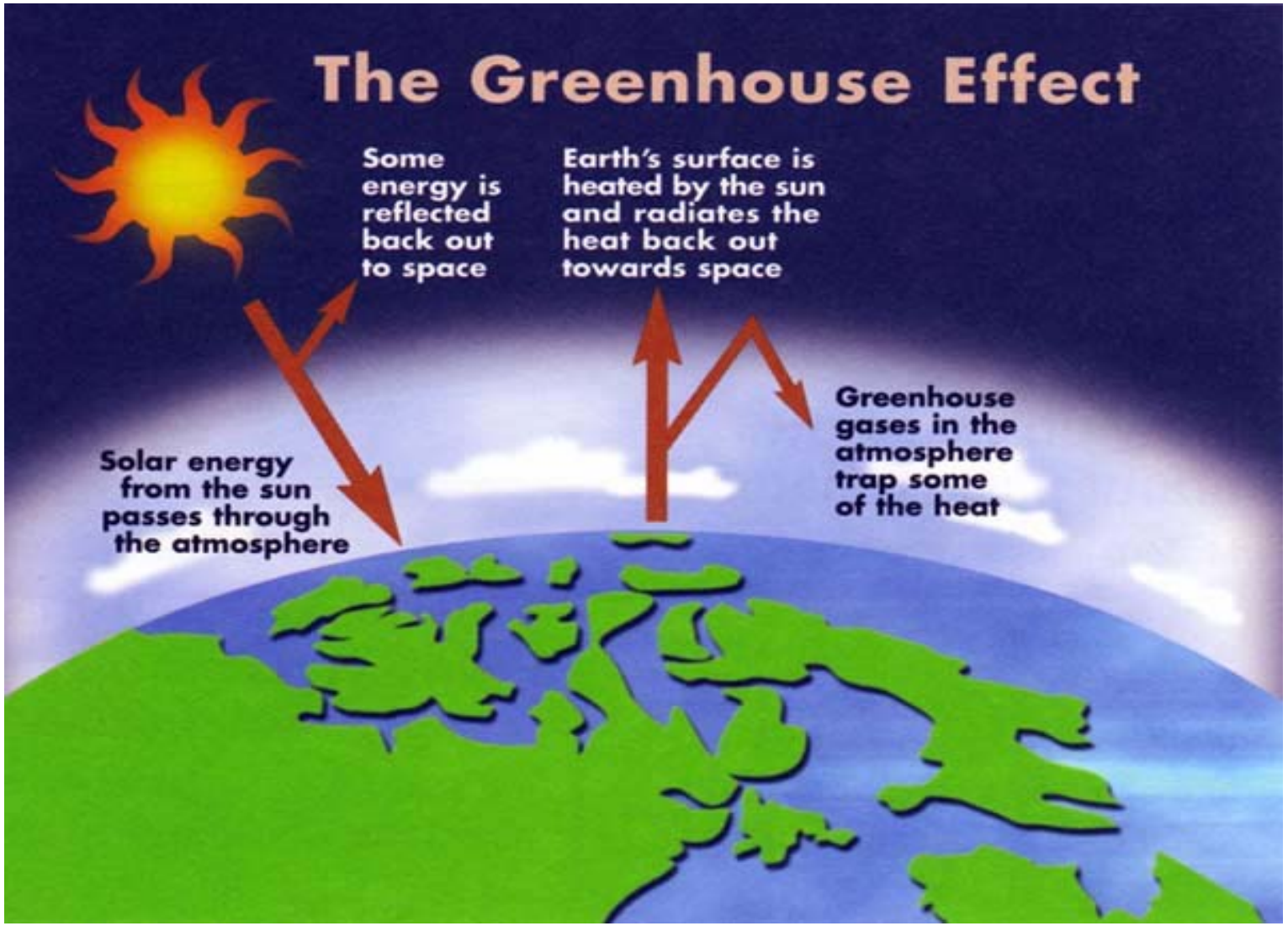

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